# A bibliometric analysis of collaboration between Brazil and Spain in the field of medical research from 2002 to 2011

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## Abstract

This study analyzes the development of Spanish-Brazilian collaborative scientific production in the field of medical research between 2002 and 2011, identifying the most productive institutions, the proportion of researchers from each country and bi-lateral collaborative networks. Data were gathered from the Scopus database, which offers broad, international coverage of multidisciplinary research. A study sample of 1,121 original scientific articles signed by 13,906 researchers were retrieved, on the basis of which the annual

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growth rate of Spanish-Brazilian medical research was calculated. A remarkably high degree of internationalization was found, with 121 countries participating in the papers sampled. Moreover, Fully 51 countries in this international network boast at least 15 contributions. The study finds a high degree of collaboration between Spain and Brazil, and significant growth of collaboration in the area of medical research, including collaborations with other countries, with fully 58 % of the sample involving a third country.

**Keywords**: Collaboration networks; scientific collaboration; Brazil; Spain; Medicine.

## Resumen

**Un análisis bibliométrico en el área de la Medicina: colaboración científica entre Brasil y España (2002-2011)**
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Esta investigación tiene por objetivo analizar la evolución temporal de la producción científica en colaboración entre Brasil y España en el área de la Medicina, en el periodo 2002-2011, además de identificar las instituciones y países más productivos y representar y analizar las redes de colaboración institucional entre los países colaboradores. Como fuente de información se utilizó Scopus, por considerarla como la principal base de datos multidisciplinar y con mayor cobertura geográfica. Los documentos analizados se han limitado a los artículos originales. Se recuperaron 1 121 artículos científicos, con un total de 13 906 firmas. Se calculó, para cada año, la tasa de crecimiento anual de la colaboración científica entre Brasil y España. Es significativo reseñar que han participado instituciones de 121 países diferentes, lo que demuestra el alto grado de internacionalización de los trabajos recogidos, y una red de colaboración científica en la que participan 51 países con al menos 15 contribuciones. Se constata el alto grado de colaboración entre estos dos países y el aumento significativo desarrollado a lo largo de los años en el área de la Medicina, así como su participación con otros países, si bien resulta importante resaltar que en más de la mitad de los trabajos (58 %) se ve

implicado un tercer país, impulsando la cooperación internacional.

**Palabras clave**: Redes de Colaboración; Colaboración Científica; Brasil; España; Medicina.

## Introducción

By the end of the 1990s and into the early twenty-first century, Brazil and Spain were among the eleven countries exhibiting the largest growth in scientific activity (Glänzel, Leta and Thijs, 2006). The participation of Brazil from 2002 to 2006 increased across all fields of knowledge, taking the lead in Latin America while accounting for 50% of scientific output from the region. In Brazil, medicine is one of three fields exhibiting the greatest growth in scientific output, featuring intense collaboration across Latin America, North America and Europe, and especially with Spain (IRD e IEDCYT-CSIC, 2009).

Consequently, Brazilian output that is internationally indexed has grown by 38.4 % in the study window. This figure vastly outperformed the world-wide rate of 19%. Brazilian output from the field of medicine has been significant, while botany and zoology have grown considerably across Latin America (IRD and IEDCYT-CSIC, 2009; FAPESP, 2011).

The development of Spain on the international stage has seen scientific output double from 2000 to 2010. In 2001, we find 28,062 documents and by 2010 this figure grew to 66,655. Spanish scientific production has grown considerably in recent years, moving from 2.5% of world output between 2003 and 2007 to 2.8% in the period of 2006-2010. Since 2008, Spanish scientific output has approached 3.0% of world output, and it has diversified into more fields. Despite this increase in output, Spain slipped from ninth place to tenth in the world rankings of scientific production, largely because of rapid growth of other emerging countries such as India.

Spain has diversified in terms of the scientific field in which it publishes, especially since 2006. By 2010, Spanish researchers had published in 288 distinct scientific areas. As has been the case in previous years, Medicine outperformed other field with 21.4% of all Spanish output in 2010, followed by Agriculture and Biological Sciences (8.8 %), Biochemical and Molecular Biology (8.3 %), Chemistry (6.8 %) and Psychology (6.6 %) (Moya-Anegón, 2013).

According to the Scopus data base and others associated to the cited questions, from 1996-2011 Brazil and Spain are the leading producers in

the field of medicine in the Portuguese- and Spanish-speaking world (Elsevier B.V. 2014). In this context, the growth rate of collaborative scientific output between Brazil and Spain is in general higher than the growth rate of each country alone during study window, as can be seen in data from SCImago (2013).

Scientific collaboration between countries has served to consolidate the internationalization of new knowledge and the science produced (Glänzel, 2003). This author studied the relationship between productivity and scientific collaboration, showing that both are related, especially in some fields such as biomedicine and chemistry.

According to studies examining scientific output world-wide, international collaborative research papers have more impact and visibility in the scientific community, a situation that motivates governments to propose initiatives aimed at encouraging collaboration among researchers (Glänzel and Lange, 2002; Persson, Glänzel and Dannell, 2004; Iribarren-Maestro, Lascurain-Sánchez and Sanz-Casado, 2009).

At the extramural level, mainly among countries, scientific collaboration has become an indispensable practice for achieving a critical mass capable of impelling and consolidating the internationalization of new knowledge and the analysis of science produced (Katz y Martin, 1997; Glänzel, 2003).

Scientific collaboration among authors, institutions or countries reflects the role of the exchange of ideas, in which a set of central objectives of a project are identified, which implies division of labor among researchers, as well as fluid communication of information, thereby broadening the likelihood of establishing new foci and tools that encourage construction networks in which collaborators interact (Balancieri et al., 2005; Olmeda-Gómez, Perianes-Rodríguez and Ovalle-Perandones, 2008).

Co-authorship serves as an indicator of scientific collaboration. An advantage of this indicator is that it is comprised of objective data that can be verified by other researchers. Moreover, it represents an accessible, friendly way to quantify collaboration, allowing researchers to work with a large universe of data that yields statistically significant results without the weakness inherent in the "case study" approach (Katz y Martin, 1997). The analysis of co-authorship suggests the possible role of sharing among researchers and, as gauged by the number of co-authored papers enjoying the support of diverse institutions and countries, constitutes a useful approach for identifying and mapping regional, national or international cooperation. Therefore, the analysis of co-authorships allows us to describe and incorporate the structure of the group that can be represented by a social network. According to Wasserman and Faust (1994), the term "social network" refers to the subset

of authors and relationships existing among them. The analysis of networks aims to develop a model of the relationships between authors, in order to make a descriptive portrait of the group structure.

According to Otte and Rousseau (2002), the analysis of social networks is an interdisciplinary procedure whose aim is to examine social structures. Moreover, they stress that analysis of social networks focuses on the relationship between authors; however, both relationship links and individual features are required in order to attain a complete picture of a social phenomenon. Bibliometrics studies collaboration networks, citations and other forms of social interaction to be implemented and observed using a graphic representation. These studies group a broad array of indicators that can be classified in indicators of output, citations, impact and relationships (Narin, Olivastro and Stevens, 1994; Callon, Courtial and Penan, 1995; Okubo, 1997; Spinak, 1998).

The output indicators are based upon the frequency of publication of a researcher, research group, institution or country. The purpose of these indicators is to reflect their insertion in the scientific community, evidencing those that are most productive, the most prominent topic areas within a field and the leading journals publishing such research.

The indicators of relationships, based on authorship or shared citations, are used in the construction and display of the scientific collaboration and in co-citation networks comprised of researchers, institutions or countries. This is achieved through the confluent application of analytical statistical, mathematical of computational techniques. In this study, output and relationship indicators are used by means of analysis of scientific collaboration.

It is important to stress the growing importance of evaluation studies of science in medicine, taking into account the history of scientific development, the great incentives provided by funding organizations, the speed of production with regard to the high volume of scientific literature and the consolidation of the medical field in the scientific world.

The aim of this study is to analyze the development of collaborative scientific production performed by Brazilian and Spanish researchers in the field of medicine from 2002 to 2011. We will also strive to identify the most highly productive institutions and countries and represent and analyze these institutional collaborative networks. We seek to enhance the picture of the development of scientific collaboration in the field of medicine performed by researchers from Brazil and Spain, while underlining the major institutional players contributing to the consolidation of the collaborative scientific network and analyzing the main areas of scientific research by the researchers of each country. This approach provides an important update to the state of

the art in this area of study in Latin America, and can serve as a tool in science policy decision making.

## Methods

The data examined were downloaded from the Sciverse Scopus data base on October 21, 2012. The search strategy included the following condition: at least one Spanish and one Brazilian researcher had to participate in the paper. This was achieved using the following search entries: Spain OR espanha or España and brasil or Brazil. Moreover, all papers included in the research sample had to be original research, published in the window from 2002-2011 and address the field of medicine.

The 1,121 papers retrieved were loaded to *Bibliométricos*, an ad hoc data base using Microsoft Access software. From there, standardization processes were performed on the imported data in order to extract results.

The names of the institutions were standardized to the level of macro-institution (university, hospital, hospital complex, company, etc.), thereby eliminating redundancies in order to secure an accurate count of institutional collaboration. For those papers signed by an author with multiple institutional affiliations, these macro-institutions were duly included in order to accurately reflect the scientific output of each.

In order to evaluate the annual proportional development of the general and collaborative scientific output of the two countries, the following formula was employed:

$$T_C(X_t) = \frac{X_t - X_{t-1}}{X_{t-1}} * 100$$

Where $T_C(X_t)$ is the growth rate of scientific output in year $t$; $X_t$ is scientific production in year t and $t$ y $X_{t-1}$ is scientific production in year *t-1*.

The analysis of topic area was performed by identifying the nuclear journals available through the portal Scimago Journal & Country Rank created by Elsevier B.V. (SCImago, 2013).

In order to treat all of the information, calculate the bibliometric indicators and the social networks, and build the graphic representations of the institutional and country clusters, Pajek open code analysis and display software was used (Batagelj and Mrvar, 2008).

## Results

Table 1 shows the annual variation in the number of papers produced in collaborations involving Brazil and Spain, the yearly percentages and the annual growth rate. We can see that the absolute number of collaborative papers published is growing, reaching a level in 2011 that is six times the output seen in 2002. The final three years of the study period contains fully 50% of the collaborative output of these two countries.

*Table 1.* Collaborative research between Brazil and Spain over the period 2002-2011

| Year | No. of collaborative papers in Medicine (Brazil and Spain) | % | CGR Medicine | General CGR (Brazil and Spain) | General growth rate (Brazil) | General growth rate (Spain) |
|---|---|---|---|---|---|---|
| 2002 | 33 | 2,90% | - | 195 | 13.210 | 23.973 |
| 2003 | 45 | 4,00% | 36,40% | 219 (12%) | 14.253 (8%) | 25.887 (8%) |
| 2004 | 51 | 4,60% | 13,30% | 264 (21%) | 16.085 (13%) | 27.803 (7%) |
| 2005 | 64 | 5,70% | 25,50% | 292 (11%) | 17.470 (9%) | 29.851 (7%) |
| 2006 | 85 | 7,60% | 32,80% | 439 (50%) | 24.636 (41%) | 35.184 (18%) |
| 2007 | 102 | 9,10% | 20,00% | 484 (10%) | 27.572 (12%) | 38.443 (9%) |
| 2008 | 137 | 12,20% | 34,30% | 589 (22%) | 31.016 (12%) | 41.168 (7%) |
| 2009 | 161 | 14,40% | 17,50% | 626 (6%) | 34.107 (10%) | 44.575 (8%) |
| 2010 | 222 | 19,80% | 37,90% | 812 (30%) | 37.311 (9%) | 47.923 (8%) |
| 2011 | 221 | 19,70% | -0,50% | 978 (20%) | 40.480 (8%) | 52.367 (9%) |
| Total | 1.121 | 100,00% | | 4.891 | 256.130 | 367.174 |
| Growth rate 2002-2011 | | | 569,69% | 401,00% | 206,43% | 118,44% |

* CGR = Collaborative growth rate; Br = Brasil; Esp = España

The growth rate of Brazilian-Spanish collaborative research over the course of the study window is positive and above the total growth rate of these countries, especially in the years 2003, 2004, 2006, 2010 and 2011, while excepting 2007 and 2009, where we see the inverse. The growth rates of each

country show how, except for the year 2011, Brazilian scientific output has been out in front of Spanish output for the entire study window, especially in 2010 when the collaboration growth rate is at least three times higher than the output rates of these countries. Of the 1,121 papers analyzed, 474 (42.2 %) were written exclusively by Brazilian and Spanish authors. Of these, 204 (43 %) papers were indexed solely in the field of Medicine, without interaction with associated areas.

Scientific collaboration is expanding, though it varies from field to field. In our study, this collaboration is latent in 100% of the works, since we started from the premise that they were signed by at least one author /a Spanish/a and other/a Brazilian/a.

The premise of this study provides at least one Spanish and one Brazilian researcher. As such, all of the sample papers are signed by at least two researchers. The 1,121 papers contained 13,906 researcher signatures. Those signed by five led all other configurations, comprising 10.44% of the sample, while those signed by six and seven authors comprised 9.55%. Table 2 breaks down the papers by number of authors, with papers signed by an excessive number of researcher lumped into one group. Interestingly, the sample include papers signed by 246, 149, 129 and 115 authors.

*Tabla 2.* Numero de autores firmantes por trabajos (2002-2011)

| No. Of signing authors / paper | Papers | % Papers | Total Signature | % Signature |
|---|---|---|---|---|
| 1* | 8 | 0,71% | 8 | 0,06% |
| 2 | 34 | 3,03% | 68 | 0,49% |
| 3 | 53 | 4,73% | 159 | 1,14% |
| 4 | 74 | 6,60% | 296 | 2,13% |
| 5 | 117 | 10,44% | 585 | 4,21% |
| 6 | 107 | 9,55% | 642 | 4,62% |
| 7 | 107 | 9,55% | 749 | 5,39% |
| 8 | 88 | 7,85% | 704 | 5,06% |
| 9 | 74 | 6,60% | 666 | 4,79% |
| 10 | 64 | 5,71% | 640 | 4,60% |
| 11 | 40 | 3,57% | 440 | 3,16% |
| 12 | 33 | 2,94% | 396 | 2,85% |
| 13 | 32 | 2,85% | 416 | 2,99% |

| | | | | |
|---|---|---|---|---|
| 14 | 21 | 1,87% | 294 | 2,11% |
| 15 | 21 | 1,87% | 315 | 2,27% |
| 16 | 13 | 1,16% | 208 | 1,50% |
| 17 | 12 | 1,07% | 204 | 1,47% |
| 18 | 20 | 1,78% | 360 | 2,59% |
| 19 | 17 | 1,52% | 323 | 2,32% |
| 20 | 17 | 1,52% | 340 | 2,44% |
| 21 | 14 | 1,25% | 294 | 2,11% |
| 22 | 13 | 1,16% | 286 | 2,06% |
| 23 | 8 | 0,71% | 184 | 1,32% |
| 24 | 11 | 0,98% | 264 | 1,90% |
| 25 | 9 | 0,80% | 225 | 1,62% |
| 26 | 4 | 0,36% | 104 | 0,75% |
| 27 | 6 | 0,54% | 162 | 1,16% |
| 28 | 9 | 0,80% | 252 | 1,81% |
| 29 | 12 | 1,07% | 348 | 2,50% |
| 30 | 9 | 0,80% | 270 | 1,94% |
| 31-50 | 55 | 4,91% | 2.103 | 15,12% |
| 51-100 | 15 | 1,34% | 962 | 6,92% |
| > 100 | 4 | 0,36% | 639 | 4,60% |
| Total | 1.121 | 100,00% | 13.906 | 100,00% |
| * These 8 originals are signed by authors as a group and have been counted as a single author. | | | | |

The collaboration index in the ten-year study window is 12.4 authors per paper. The collaboration index was between nine and twelve authors during the first eight years of the study window and grew rapidly over the remaining two years to 13.72 in 2010 and 15.09 in 2011. The aforementioned papers with exorbitant numbers of signing authors were found in this two-year segment.

Papers with Brazilian-Spanish collaboration were published in 581 distinct journals. Those areas with the highest proportions were immunology (92 journals), General Medicine (73), Oncology (48), Endocrinology (38), followed by Neurology and Public Health, Environment and Occupational

Health each with 35 journals. The journals publishing the highest number of Brazil-Spain collaborative papers are *Plos One* and *New England Journal of Medicine*, each with 18; *Annals of the Rheumatic Diseases* and *Journal of Clinical MIcrobiology* with 12 each; and *Arquivos de Neuro-Psiquitaria* with 10. We find that Brazil-Spain collaborative papers are most frequently published in journals from the United States of America and the United Kingdom. Moreover, these collaborative works account for the percentages of all papers published in the following journals: United Kingdom participates with 179 journals (31%) and 307 papers (27,4 %); the United States contributes 178 journals (30 %) but with a larger number of papers at 389 (34.7 %). Meanwhile, Spain contributes 49 journals (8.4 %) and 102 papers (9 %), and Brazil pitches in with 43 journals (7.4 %) but with 112 papers (10 %). Fully 23 % of the balance of journals are spread among 24 countries, accounting for 211 papers (18.9 %).

Institutional collaboration, in which at least one Brazilian and one Spanish intuition are credited, s found in 2,897 distinct institutions. There 178 papers (15.88%) were signed by the minimum of one Brazilian and one Spanish institution, while 212 (18.91%) were signed by three and 151 (13.74%) by four. At the other extreme, one paper was found that credited 138 distinct institutions.

Viewing the data in terms of the country affiliations, we find a different picture, with 484 papers, or 43.18 % of the sample, signed by two countries (in this case Brazil and Spain), 161 signed by three countries (14.36%) and so on until we reach one paper signed by 42 distinct countries. Of the 2,897 institutions credited in the sample, 411 are Spanish and 299 are Brazilian. Table 3 provides a breakdown by country of institutions credited in twenty or more papers. Interestingly, there are several institutions with more than 100 credits, with Universidade de São Paulo (USP) boasting 222 papers followed by Hospital Clínic i Provincial de Barcelona with 102 papers. Other outstanding institutions in this sphere are Universidad de Buenos Aires with 48 papers and University of Toronto with 36 papers. The data shows a slight preponderance of universities over research hospitals, health centers and research institutes.

*Table 3.* Most productive institutions by country (Spain, Brazil and others) least 20 documents (2002-2011)

| Country | Institution | Nº Doc. |
|---|---|---|
| Brazil | Universidade de São Paulo (USP) | 222 |
| | Fundação Oswaldo Cruz (FIOCRUZ) | 97 |
| | Universidade Federal de São Paulo (UNIFESP) | 95 |
| | Universidade Federal do Rio de Janeiro (UFRJ) | 94 |
| | Universidade Federal do Rio Grande do Sul (UFRGS) | 82 |
| | Hospital de Clínicas de Porto Alegre (HCPA) | 79 |
| | Universidade Estadual de Campinas (UNICAMP) | 51 |
| | Universidade Estadual Paulista (UNESP) | 47 |
| | Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo (HCFMUSP) | 47 |
| | Universidade Federal de Minas Gerais (UFMG) | 44 |
| | Universidade Federal de Pelotas (UFPEL) | 24 |
| | Santa Casa de Misericórdia de Porto Alegre | 24 |
| | Pontifícia Universidade Católica Do Rio Grande Do Sul (PUCRS) | 21 |
| Spain | Hospital Clínic i Provincial de Barcelona | 102 |
| | Universitat de Barcelona | 92 |
| | Universitat Autònoma de Barcelona | 62 |
| | Instituto de Salud Carlos III | 54 |
| | Universidad Complutense de Madrid | 51 |
| | Complejo Universitario La Paz | 51 |
| | Universidad Autónoma de Madrid | 45 |
| | Hospitals Vall d'Hebron | 40 |
| | Universitat de València | 39 |
| | Universidad de Granada | 38 |
| | Universidad de Santiago de Compostela | 37 |
| | Universitat Rovira i Virgili | 37 |
| | Institut Català d'Oncologia (ICO) | 35 |
| | Institut d'Investigacions Biomèdiques August Pi i Sunyer (IDIBAPS) | 31 |
| | Hospital Ramón y Cajal | 27 |
| | Hospital de la Santa Creu i Sant Pau | 26 |
| | Complejo Univesitario de San Carlos | 25 |
| | Hospital General Universitario Gregorio Marañón | 24 |
| | Universidad de León | 23 |
| | Universitat Pompeu Fabra | 23 |
| | Universidad de Salamanca | 22 |
| | Hospital de Sant Joan de Déu | 22 |
| | Hospital Universitari de Bellvitge | 22 |
| | Consorcio de Investigación Biomédica de Epidemiología y Salud Pública (CIBERESP) de Barcelona | 22 |
| Argentina | Universidad de Buenos Aires (UBA) | 48 |
| Canada | University of Toronto | 36 |
| Austria | Medical University of Vienna | 32 |
| Belgium | University Hospitals Leuven | 30 |

| | | |
|---|---|---|
| United States | Duke University Medical Center | 30 |
| France | Université Paris V René Descartes | 29 |
| France | Institut National de la Santé et de la Recherche Médicale (INSERM) | 28 |
| Germany | Charité – University Hospital Berlin | 26 |
| United States | University of North Carolina | 26 |
| Sweden | Karolinska Institutet | 26 |
| Italy | Università degli Studi di Padova | 25 |
| United States | University of Michigan | 24 |
| United States | Harvard Medical School | 24 |
| Portugal | Instituto de Patología e Inmunología Molecular (IPATIMUP) | 24 |
| France | International Agency for Research on Cancer (IARC) | 23 |
| Australia | University of Melbourne | 22 |
| Belgium | Université Catholique de Louvain | 22 |
| Italy | Università degli Studi di Milano | 22 |
| Nether-lands | University Medical Center Groningen | 21 |
| United Kingdom | University College London | 21 |

*Figure 1* represents the institutional participation network. Using a threshold of 10 or more collaborations, we can identify a nucleus or tightly woven network of institutional collaboration comprised of 64 closely linked entities. Amid this complex network, Universidade de São Paulo (USP) stands as a major hub whose links radiate to all other institutions. The participation of 10 Brazilian and 17 Spanish institutions can be observed, indicated by squares and triangles, respectively. These institutions are linked to 64 distinct countries, including most notably Universidad de Buenos Aires (uba); Instituto Catalán de Oncología (ICO); Hospital Clínic i Provincial de Barcelona; the federal universities of Sao Paulo and Rio de Janeiro, and Fundação Oswaldo Cruz (Fiocruz), which establish links between Universidade de São Paulo and the remaining participating institutions.

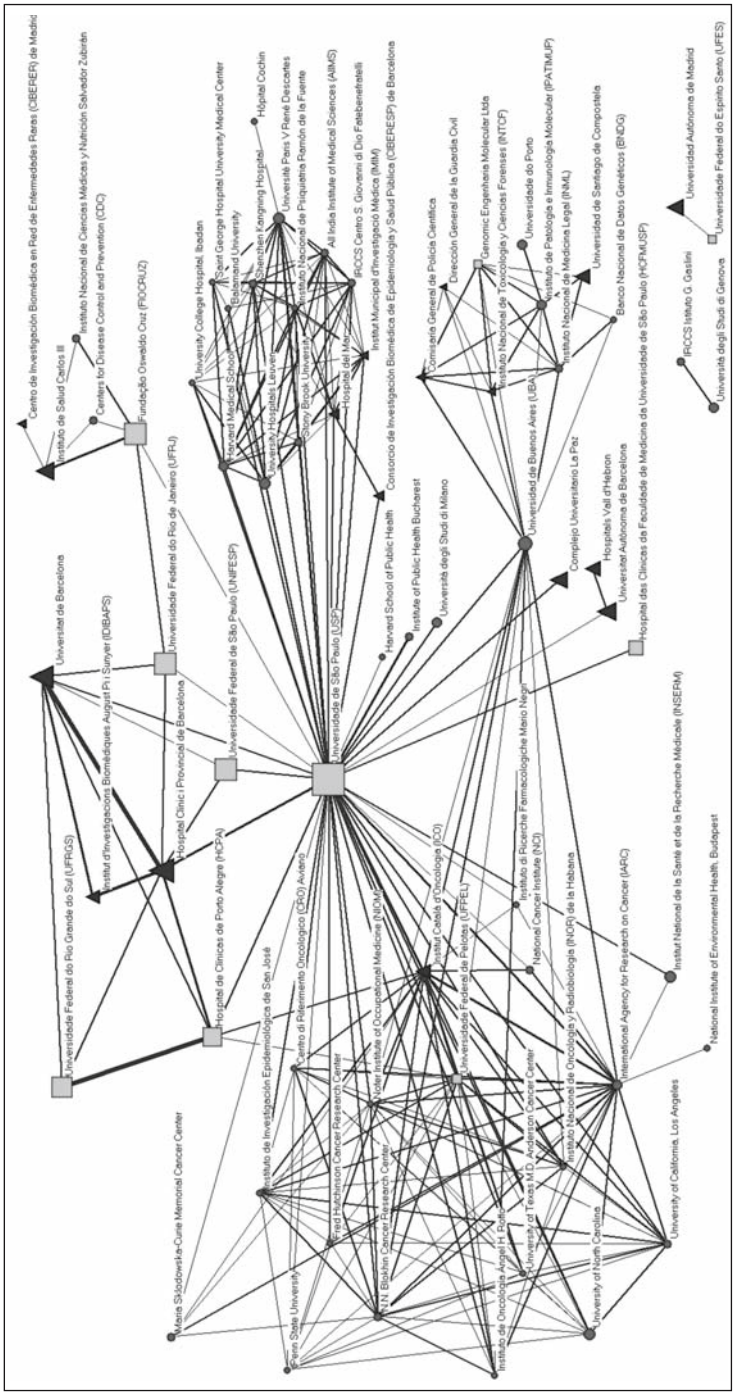


*Figure 1.* Institutional scientific collaboration network (at least 10 papers)

The most intensive collaborative work in this network is established by Hospital de Clínicas de Porto Alegre (HCPA) and Universidad Federal do Rio Grade do Sul (UFRGS) (n=40 jointly-signed papers); el Hospital Clínic i Provincial de Barcelona and Universitat de Barcelona (at n=39) and the former with Institut d'Investigacions Biomèdiques August Pi i Sunyer (IDIBAPS) ( at n=27); Fundação Oswaldo Cruz (FIOCRUZ) and Instituto de Salud Carlos III (at n=22); and again Hospital Clínic i Provincial de Barcelona and el Hospital de Clínicas de Porto Alegre (HCPA) (at n=21).

In the lower portion of *Figure 1*, one can observe two rather isolated nuclei representing Universidad Autónoma de Madrid and Universidad Federal do Espírito Santo (UFES) and two Italian institutions: la Universitá degli Studi di Genova and IRCCS Istituto G. Gaslini.

The distribution of papers by country in collaboration with Brazilian and Spanish institutions is shown in Table 4. The 2,897 distinct Brazilian and Spanish institutions have appeared 5,994 times and correspond to 121 distinct countries on five continents. The United States of America is the country publishing the most papers with 357 papers and 389 distinct institutions, followed by France with 231 documents and 117 institutions, while Italy, United Kingdom, Germany and Argentina follow. Spain contributes 411 distinct institutions and Brazil 299.

*Table 4.* Number of documents and institutions by country (2002-2011)

| Country | Nº Inst. | Nº Doc | Country | Nº Inst. | Nº Doc |
|---|---|---|---|---|---|
| Albania | 2 | 1 | Israel | 18 | 73 |
| Germany | 115 | 191 | Italia | 141 | 206 |
| Angola | 1 | 1 | Japan | 66 | 59 |
| Saudi Arabia | 4 | 8 | Kenia | 2 | 3 |
| Argentina | 1 | 1 | Kirghizstan | 1 | 1 |
| Algeria | 2 | 4 | Kuwait | 1 | 1 |
| Argentina | 79 | 155 | Latonia | 5 | 14 |
| Australia | 60 | 100 | Lebanon | 6 | 22 |
| Austria | 18 | 59 | Lithuania | 5 | 11 |
| Bangladesh | 2 | 2 | Luxemburg | 3 | 4 |
| Belgium | 29 | 96 | Madagascar | 1 | 2 |
| Bolivia | 10 | 11 | Malaysia | 4 | 5 |
| Bosnia y Herzegovina | 1 | 1 | Malawi | 2 | 2 |
| Botswana | 1 | 1 | Mali | 1 | 1 |
| Brazil | 299 | 1.121 | Malta | 2 | 2 |
| Bulgaria | 9 | 23 | Morocco | 6 | 6 |
| Burkina Faso | 1 | 1 | México | 66 | 117 |
| Cambodia | 1 | 1 | Mozambique | 2 | 2 |

| | | | | | |
|---|---|---|---|---|---|
| Cameroon | 1 | 1 | Nepal | 1 | 1 |
| Canada | 88 | 148 | Nicaragua | 1 | 1 |
| Chile | 23 | 48 | Nigeria | 5 | 17 |
| Cyprus | 1 | 1 | Norway | 26 | 41 |
| Colombia | 41 | 79 | New Zealand | 10 | 27 |
| Congo | 1 | 1 | Netherlands | 31 | 124 |
| South Korea | 17 | 20 | Pakistan | 1 | 1 |
| Costa Rica | 12 | 38 | Palestine | 1 | 1 |
| Croatia | 10 | 18 | Panama | 7 | 6 |
| Cuba | 14 | 25 | Papua New Guinea | 1 | 1 |
| Denmark | 17 | 45 | Paraguay | 9 | 11 |
| Ecuador | 16 | 18 | Peru | 25 | 40 |
| Egypt | 6 | 6 | Poland | 25 | 65 |
| El Salvador | 5 | 4 | Portugal | 35 | 70 |
| U. Arab Emirates | 6 | 8 | Puerto Rico | 5 | 10 |
| Slovakia | 12 | 29 | Qatar | 1 | 1 |
| Slovenia | 2 | 7 | United Kingdom | 129 | 197 |
| Spain | 411 | 1.121 | Czech Republic | 15 | 40 |
| United States | 389 | 357 | Republic of Chad | 1 | 1 |
| Estonia | 5 | 9 | Dominican Republic | 4 | 4 |
| Ethiopia | 2 | 2 | China | 20 | 44 |
| Filipinas | 3 | 8 | Rumania | 12 | 42 |
| Finland | 28 | 49 | Russia | 14 | 38 |
| France | 117 | 231 | Senegal | 1 | 1 |
| Gambia | 1 | 2 | Serbia y Montenegro | 8 | 13 |
| Georgia | 2 | 2 | Singapore | 9 | 22 |
| Ghana | 2 | 2 | Syria | 1 | 1 |
| Greece | 25 | 45 | South Africa | 18 | 44 |
| Guadalupe | 1 | 3 | Sweden | 20 | 67 |
| Guatemala | 8 | 7 | Switzerland | 30 | 90 |
| French Guiana | 2 | 3 | Thailand | 10 | 20 |
| Guyana | 1 | 1 | Taiwan | 15 | 22 |
| Haiti | 1 | 1 | Tanzania | 4 | 3 |
| Honduras | 4 | 7 | Tunis | 5 | 5 |
| Hong Kong | 5 | 28 | Turkey | 20 | 34 |
| Hungary | 21 | 46 | Ukraine | 5 | 9 |
| India | 35 | 52 | Uganda | 1 | 2 |
| Indonesia | 2 | 1 | Uruguay | 16 | 27 |
| Iran | 7 | 5 | Venezuela | 22 | 33 |
| Iraq | 1 | 2 | Vietnam | 2 | 2 |
| Ireland | 13 | 22 | Zambia | 1 | 1 |
| Iceland | 2 | 8 | Zimbabwe | 2 | 2 |
| Faeroe Island | 1 | 1 | | | |

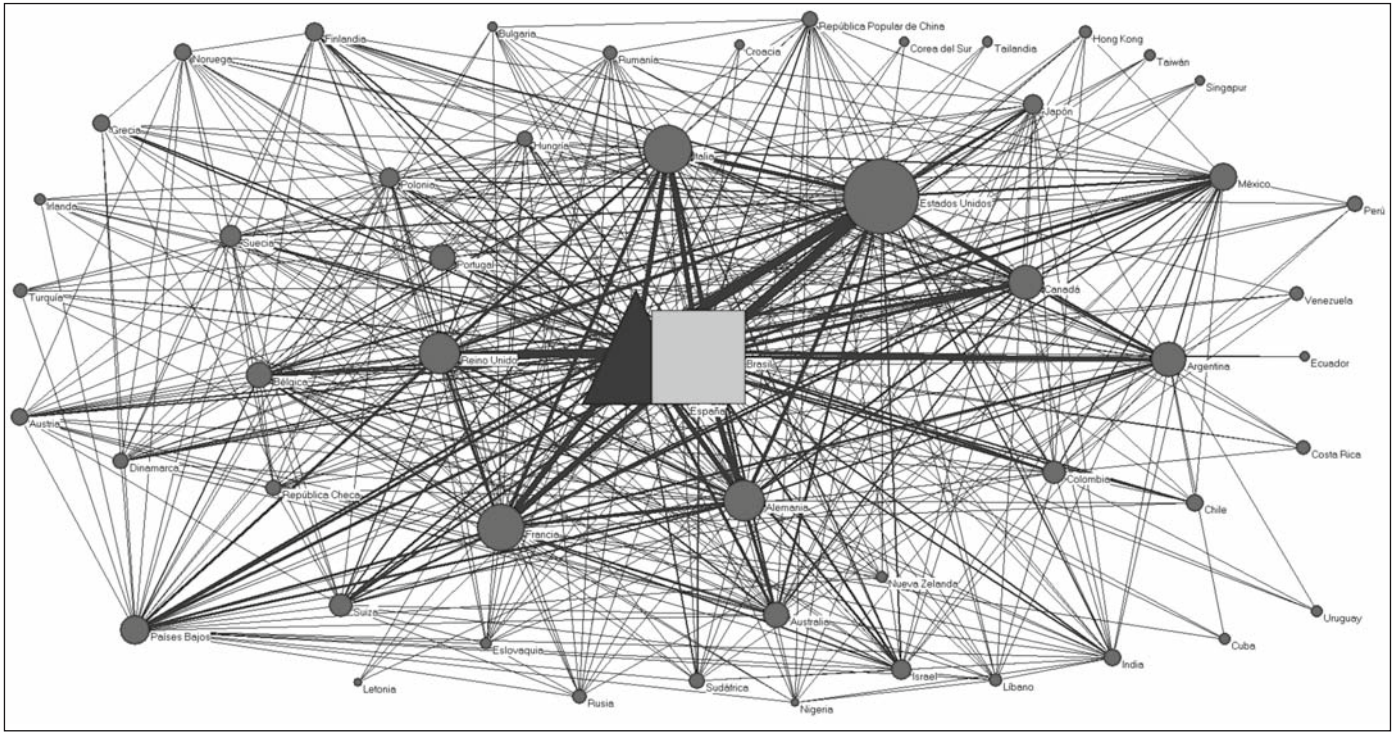


*Figure 2.* Network of countries collaborating with Brazilian-Spanish collaborative scientific research (at least 15 papers)

*Figure 2* illustrates the collaboration network by country among institutions with at least 15 collaborative papers. Since this study brings together Brazilian and Spanish collaboration, this network occupies the center region of the chart depicting 1,121 papers. In additional to Brazil and Spain, there are 51 countries boasting at least 15 collaborative papers.

The United States, Canada, Japan, China, Australia, New Zealand, Germany, Italy, United Kingdom, France India and Mexico stand out with regard to scientific output. Proximity also plays a role in the collaboration network of ten countries in South and Central America, and twenty-two counties of the EU. These data reveal a high degree of collaboration that is constantly growing, as well as the growing internationalization of Brazilian and Spanish research in the field of Health Sciences.

## Discussion

This paper provides a comprehensive picture of Brazilian-Spanish scientific collaboration that integrates bibliometric and social network analyses. A key result of our research shows that the collaboration between these two countries increased seven-fold during the study window (2002-2011). Additionally, the growth rate of this collaboration was greater than the growth rates of either country alone.

Several previous analyses show Clinical Medicine as the most highly productive field of Latin American research, accounting for nearly a fourth of the papers published in this field (De Filippo and Gómez, 2011). The individual growth of Brazil is in line with the results of previous research. These studies include: Leta and Chaimovich (2002), Leta, Glänzel and Thijs (2006) and Glänzel, Leta and Thijs (2006), which show that Brazil moved from a collaboration rate of 21.6% in the 1980s to 26.7% in the decade of the 1990s. Meanwhile, Brazil maintains its lead in overall Latin American research, with an annual growth rate of 8.0%, although this growth is behind that of Mexico (Glänzel, Leta and Thijs, 2006). Brazil's leadership exists also in the fields of Public Health, where it is first among Latin American countries and sixth in the world overall, followed by Mexico, Cuba, Colombia and Argentina (Zacca *et al*., 2014).

Brazil's leadership can be explained by the fact that investment in research and development accounts for 60% of such investment in the entire region (Babini, 2011). This has driven Brazil into the lead in terms of international collaboration and an enviable strategic position while enjoying a high number of relationships (Chinchilla-Rodríguez, Benavent-Pérez and

Moya-Anegón, 2012). Brazil's output is also growing across several other fields, including ceramics (Rojas-Sola and Jordá-Albiñana, 2009), psychology (Sánchez-Sosa, 2008; Vera-Villarroel *et al*, 2011) and sanitation technology (Pichon-Riviere, Ceballos and Briones, 2009). With regard to Spain, recent studies have shown sustained growth in areas such as Neurology (González-Alcaide et al, 2008), Bronchial-Pulmonology (Granda Orive *et al*., 2009),Cardiology (Aleixandre-Benavent et al., 2009) and Pediatrics (Alonso-Arroyo *et al*., 2013).

The slackening of the diaspora of Brazilian scientists, which occurred during the dictatorships, and new incentives to speed up scientific production have also aided the growth of Brazilian science. This growth creates a need to evaluate (Gracio and Oliveira, 2012) the number of students in higher education and development of new plans for channeling human resources into scientific activities, especially by the introduction of master's and doctoral degree programs and specific research initiatives, such as the Fellowship Initiation in Science (Leta, Glänzel and Thijs, 2006). These efforts have led to the formation of more highly qualified researchers (Glänzel, Leta and Thijs, 2006). Other factors driving this growth is the increasing number of Latin American science journals included in bibliographic data bases over the last decade. In several countries, such as Argentina, Chile, Mexico and Venezuela, the number of journals has increased threefold. The coverage of Latin American journals in international bibliographic data bases, however, is still quite low and, consequently, high quality work from Latin America is generally published in the United States of America or in European journals (Aleixandre *et al*., 2013).

Despite this growth in the number of papers published, some problems persist in terms of instability in the budgetary allocations for research issued by public agencies. According to the World Bank, the gross domestic product (GDP) devoted to Brazilian research in 2011 was 1.21 %, which is higher than that reported in other Latin American countries, such as Chile (0.42 %), Mexico (0.43 %) and Argentina (0.65 %); but still quite a bit lower than that seen in developed countries. In Spain, this figure is 1.36 %, which is one of the lowest in the EU, with the UK at 1.78% and Germany at 2.89%, according to the World Bank (2011). Despite these factors, in the decade of 1999 to 2008, Spain and Brazil increased R&D investment more than any other country in the Iberian world. Similarly, they have the highest number of researchers in the region, according to full-time equivalent calculations (Albornoz, 2010).

Collaboration is fundamental for scientific development, in that it promotes efficiency in national research, development and innovation by

allowing researchers to integrate international teams that share resources and new techniques (Cunningham and Dillon, 1997; Katz and Martin, 1997; Newman, 2004). The phenomenon of collaboration is heterogeneous and this has been shown by numerous researchers, such as Beaver (2004), Newman (2004), Glänzel and Schubert (2001), and others. The weightiest factors in its genesis and maintenance are economic, geopolitical and intra-scientific (Glänzel and Schubert, 2001). International collaboration can reflect individual mobility, the interests of individual scientists, or the economic or political dependence of a country or region; but also the need to ensure access to special equipment for multinational research projects. In the health sciences, this can even be owing to biological factors, such as the prevalence of certain diseases in a given country.

The creation of networks and groups of scientists and technicians from diverse countries is a key aspect of cooperation strategies, because they promote the march of knowledge, while enhancing quality and impelling innovation and competitiveness (Cunningham and Dillon, 1997; Aleixandre et al., 2013). Moreover, international collaboration is a positive sign that indicates a country is opening up to foreign research. It has been reported, moreover, that collaborative research produces results with significantly greater authority, which is reflected in frequency of citations and longer duration of influence (Beaver, 2004).

An earlier study by Mugnaini *et al.* (2014) analyzed the collaboration between Brazil and Spain by field, showing that this collaboration centered mostly on clinical and experimental medicine in accord with the classification proposed by Glänzel and Schubert (2003). Their approach groups the Web of Science field into 15 large categories. Brazil collaborates most often with the EU, Central America and the United States of America, which accounts for 40.5% of their international collaboration. Collaboration also grew with other countries in the region, including Mexico and Argentina, as shown in a study performed by Glanzel, Leta and Thijs (2006). These data serve to ratify the results presented by IRD and IEDCYT-CSIC (2009) in the period from 2002 to 2006, which also reveals a broad collaboration network involving Latin America and Europe. One earlier study shows that most of the collaboration in the field of clinical medicine is occurring between Brazil-United Kingdom, followed by Brazil-Italy and Brazil-France. Collaboration with Spain came in sixth place (De Filippo and Gómez, 2011). According to the Thomson Reuters Global Research Report for Brazil, drafted on the basis of Web of Science data bases (Adams and King, 2009), the United States of America is the main collaborator of Brazil, followed by France, United Kingdom, Germany, Italy and Canada. Spain stands in seventh place in

said study, but doubled its collaboration tally from the five-year windows of 1998-2002 to 2003-2007, moving from 1,245 to 2,382 papers, respectively, with latter window accounting for 19% of Brazil's total output.

Government policies promoting collaborative research in both countries must lie at the foundation of this growth. Scientific collaboration between Spain and Brazil has also brought broad participation of researchers from 121 countries, led by the United States of America and followed by EU countries such as France, Italy, United Kingdom, Germany and Argentina. This is to be expected, since it is a consequence of EU policies that seek cohesion in the research efforts of its member countries.

Brazil's scientific capacity in the field under study is concentrated in certain institutions, largely in the wealthiest states. It is evident that other states should have research centers, but so far such efforts are best termed incipient. We stress the key role of Universidade de São Paulo in the scientific collaboration network and another ten Brazilian and seventeen Spanish institutions that collaborate with sixteen countries. We may also stress institutions such as Universidad de Buenos Aires, Instituto Catalán de Oncología, Hospital Clínic i Provincial de Barcelona, the federal universities of São Paulo and de Rio de Janeiro, and Fundação Oswaldo Cruz.

## Limitations of the study

This study has some limitations that should be discussed. In the first place, Scopus does not include all of the scientific medical literature published. As such, other bibliographic data bases that gather Latin American scientific journals could have been used alternately or in a complementary way. We opted to use Scopus, however, because of the following advantages: a) It is used widely in studies of scientific activity, since it includes the major journals published around the world (Rojas-Sola and Jordá-Albiñana, 2009; Michán and Llorente-Bousquets, 2010); b) It provides the names of all the institutional affiliations participating in the papers, which allows us to determine the cooperation indicators between institutions and countries. In the second place, this study does not show the scientific contribution of the collaboration between Brazil and Spain, because it does not provide a conceptual analysis of results. This limitation, however, offers fertile ground for additional research.

## Conclusiones

This study provides an indication of the status of scientific collaboration between Brazil and Spain in the field of medicine. Our conclusions are based on published papers that are indexed in Scopus. The results show significant growth in the number of papers published in collaboration by Brazil and Spain, their collaboration with EU and Latin American countries and with the United States of America. Our report also shows that Brazil's R&D budgets are expanding significantly in tandem with Mexico's Collaboration between Latin America and Spain will likely continue to grow in terms of intellectual and economic development. Europe and Spain have benefitted from their exports to Latin America in the past; as such they should integrate their knowledge by means of international collaboration, while ensuring full participation and guarding against marginalization. Future research in this area might identify groups of researchers who are responsible for this collaboration and the main lines of research performed in collaboration between these two countries.

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